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Transmitted herewith for filing under 35 U.S.C. 111 and 37 C.F.R. 1.53 is the patent application of:

Jean-Pierre Ferlay

For: **MOBILE COMMUNICATION SYSTEM USING LOSS CABLES AS TRANSMISSION ELEMENTS**

Enclosed are:

- ☒ Certificate of Mailing with Express Mail Mailing Label No. **EL669040972US**
- ☒ 3 sheets of drawings.
- ☐ A certified copy of a application.
- ☒ Declaration ☐ Signed. ☒ Unsigned.
- ☒ Power of Attorney
- ☐ Information Disclosure Statement
- ☐ Preliminary Amendment
- ☐ Other:

CLAIMS AS FILED

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	8	- 20 =	0	x \$18.00	\$0.00
Indep. Claims	1	- 3 =	0	x \$80.00	\$0.00
Multiple Dependent Claims (check if applicable) <input type="checkbox"/>					\$0.00
BASIC FEE					\$710.00
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Dated:

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PATENT TRADEMARK OFFICE

APPLICATION
FOR
UNITED STATES LETTERS PATENT

TITLE: MOBILE COMMUNICATION SYSTEM
USING LOSS CABLES AS TRANSMISSION
ELEMENTS

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Express Mail No.: EL669040972US

Date: November 27, 2000

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MOBILE COMMUNICATION SYSTEM USING LOSS CABLES AS TRANSMISSION ELEMENTS

TECHNICAL FIELD

5 The present invention relates to the field of cellular mobile communications and more specifically to the aspects inherent in operating cellular networks in confined or underground environments, such as tunnels.

BACKGROUND OF THE INVENTION

10 Each cell within a cellular mobile communication system is serviced by a base station. When it is switched on, a mobile station selects the base station with which it will secure the best radio link. If the mobile station is moved and changes cell, it can then re-select another base station. This selection/re-selection process takes place with the aid of a beacon signal which is transmitted on a specific frequency by each base station.

15 In many systems, the changeover of cell may also take place during a call, in which case it will be managed by a process known as « handover ». The base station providing the radio link to the mobile station sends data to it, identifying the channels on which the base stations of neighbouring cells are transmitting their beacon signals. This information may consist of a list of frequencies relating respectively to the beacon signals of adjacent cells. In
20 parallel with the communication, the mobile station monitors these frequencies. A comparison is run between the reception conditions in the cell currently being serviced and in the adjacent cells so that a decision can be taken as to the time at which the changeover of cell should be effected. Depending on the systems, this decision is taken either at the level of the mobile stations or at the level of
25 the fixed infrastructure.

In confined environments, in which radio waves are not readily propagated, the continuity of cellular mobile communication services is sometimes provided by means of transmission cables installed along the zones where service has to be provided. These cables are generally of the coaxial
30 type, having an imperfect external shield so that losses in radiation will provide radio coverage in the zone in question. These are used in railway tunnels in particular. Taking the example of an underground railway system, the base

stations of the cellular system are positioned in stations, typically spaced apart by 500 to 1500 metres, and linked to loss cables extending along the tunnels between stations.

Using loss cables poses a problem when it comes to the handover procedure because the field emitted by such a cable fades abruptly at the ends of the cable. The successive runs of cable are usually placed end to end which means that there is only very low coverage of the cells at the boundaries. Under these conditions, the mobile station does not have time to perform the steps needed with respect to the beacon signal of the adjacent cell to be able to run the handover, particularly as the mobile station is generally moving at quite a high speed (in the example of the underground railway, the boundary between two cells is usually in the middle of a tunnel between two stations, i.e. at a point where the rolling stock is travelling at full speed). Consequently, there is a risk that the call will be cut off due to the fact that the mobile station has not been able to run the requisite steps before entering a new cell.

In order to remedy this problem, publication WO97/16 892 proposes a system of overlapping successive lengths of cable belonging to two neighbouring cells over a certain length at the boundary of these cells, one of the two lengths being provided with an attenuator positioned so that it will attenuate the radiation of one of the two cables in the overlap zone. This attenuation is such that the mobile station is able to continue communicating with the base station feeding the cable equipped with the attenuator when directed towards the other cell, whilst running the necessary steps to operate the handover on the beacon signal transmitted from the other cell without any attenuation. The disadvantage of this method is that the level of the signals, already low at the ends of the cable prior to attenuation, become unusable for practical purposes once attenuated unless the overlap between the runs is relatively long. However, the cost of installing a long overlap is high, given the price of loss cables. Furthermore, the method is uni-directional: in the case of a tunnel in which trains are travelling in the two directions, handovers are only possible in one direction. Furthermore, installation requires work to be carried out in the middle of the tunnels if the railway network is equipped with pre-existing loss cables, which complicates the installation process.

Another drawback of this solution is the fact that the attenuation is applied to all the signals carried by the cables. Very often, these cables carry several mobile communication services, provided by different cellular systems and/or run by different operators. The method is therefore not suitable if only one operator wants to use it.

SUMMARY OF THE INVENTION

One objective of this invention is to overcome the disadvantages outlined above in order to facilitate the handover between two adjacent cells in a confined or underground environment such as a tunnel.

The invention proposes a mobile communication system comprising runs of loss cables disposed successively along a zone of radio coverage and feeder means for feeding the cable runs from the base stations of at least one mobile communication network. The feeder means comprise means for applying first radio frequency signals emitted from a first base station of the cellular mobile communication network to a first cable run, means for applying second radio frequency signals emitted from a second base station of the cellular mobile communication network to a second cable run which is adjacent to the first run, and means for applying at least part of the second radio frequency signals to the first cable run.

Coverage between adjacent cells is provided by means of signals launched down the successive runs of cable. This secures greater flexibility in terms of installing the means needed to operate the handover under good conditions. In particular, there is no need for work to be carried out inside the tunnel and applying the solution does not necessarily mean involving all the signals carried by the cables. Nor does this solution involve overlapping the cables across runs of any great length, which makes it attractive in terms of cost.

In order to assist the process of selecting the best cell, said part of the second radio frequency signals is preferably applied to the first cable run with a given attenuation relative to the first radio frequency signals as applied to the first cable run.

In a typical application, the overlap of cells is symmetrical, i.e. the feeder means also have means for applying at least part of the first radio

frequency signals to the second cable run, preferably with a given attenuation relative to the second radio frequency signals as applied to the second cable run.

Depending on the applications, the radio frequency signals (RF) of a cell, applied to the cable run closest to the adjacent cell, may contain all the signals transmitted by this cell or only some of them, namely the frequency carrying the beacon signal of the adjacent cell.

The system will generally incorporate means for collecting the radio signals picked up on the runs of loss cable. In one advantageous embodiment, these collection means have means for applying third radio frequency signals, which are transmitted from the first cable run, to the first base station and means for applying at least some of the third radio frequency signals to the second base station.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the present invention will become clear from the description of examples given below, which are not restrictive in any respect, and with reference to the appended drawings, of which:

- figure 1 is a synoptic diagram of a system as proposed by the invention;
- figures 2 and 3 are diagrams illustrating the coupling and amplifier devices of the system illustrated in figure 1 ; and
- figure 4 is a diagram illustrating a coupling device used in a different embodiment of the system.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 schematically illustrates deployment of a cellular mobile communication network along an underground railway line having stations 1-4 separated by tunnels 8.

Base stations (BTS) of the cellular network are disposed in some of the stations 1, 4. The antennas of these base stations 5, 6 are provided in the form of runs of loss cable 11-14 arranged one after the other along the railway systems in order to provide radio coverage inside the tunnels 8. For example, they are suspended from the roof of the tunnels 8. Each BTS 5, 6 may co-operate with several runs of loss cable, 11-12 and 13-14 respectively. The cell

served by this BTS 5, 6 corresponds to the radio coverage zone of the different cable runs co-operating therewith. In the illustration provided in figure 1, line A diagrammatically represents the boundary between the cells serviced by the BTS 5 and 6 respectively.

5 The radio stage of each BTS 5, 6 is linked to a RF/FO coupler-multiplexer 15, 16 which acts as an interface, having a bundle 25, 26 of optical fibres (FO). For the downlink, this RF/FO coupler-multiplexer 15, 16 receives the radio frequency signal S_D , S'_D transmitted by the BTS 5, 6, translates it in the form of light modulation and transmits it N times on the optical fibres of the
10 bundle 25, 26, N denoting the number of runs of loss cable co-operating with the BTS 5, 6.

Each run of cable 11-14 is supplied by a respective coaxial cable 21-24 linked to a coupling and amplifying device 31-34. In a typical layout, each of the devices 31-34, the corresponding feeder cable 21-24 and the launch point
15 (connection of the feeder cable 21-24 to the run of loss cable 11-14) is located in a station of the underground railway system 1-4.

For the uplink, the device 31-34 translates the RF signal collected by the cable run 11-14 in the form of a light modulation on an optical fibre as far as the relevant coupler-multiplexer 15, 16. The latter combines the uplink signals
20 transmitted from the different runs of loss cable co-operating with its BTS 5, 6 to form the radio frequency signal S_U , S'_U addressed thereto.

Figure 2 provides a more detailed illustration of the structure of the device 31 illustrated in figure 1, in a specific example where the radio signals S_D , S_U transmitted and received by the BTS are frequency division multiple
25 access signals (FDMA, « Frequency Division Multiple Access »). In the example illustrated here, four frequencies may be used by the BTS in each direction, namely three frequencies to support traffic channels and one frequency to support a control channel. Each traffic or control channel on the downlink has, on another frequency, a corresponding traffic or control channel
30 on the uplink. In particular, the downlink control channel carries a beacon signal specific to the cell serviced, enabling the mobile stations to select the base station and perform the steps necessary for the handover procedure. In the example described here, one optical fibre is dedicated to transmitting a specific

frequency so that the portion 38 of the bundle of optical fibres 25 linking the device 31 to the coupler-multiplexer 15 of the cell is made up of eight fibres.

For each fibre, a basic FO/RF coupler 40, 41 takes charge of the translation between the radio modulation at the coaxial cable 21 end and the light modulation at the fibre end. Amplifiers RF 42, 43 are positioned downstream of the basic couplers 40 in the downlink direction and upstream of the basic couplers 41 in the uplink direction to provide adequate signalling levels. The output signals from the amplifier 42 are combined to reconstitute the radio frequency signal S_D sent to the loss cable 11 via the feeder cable 21.

The uplink signal S_U picked up by the run of loss cable 11 is distributed to the inputs of the amplifiers 43 from the cable 21.

This signal distribution system defines the cell as being the juxtaposition of elongate zones covered by the successive cable runs 11-12 thus linked to the BTS 5. A similar distribution system may be provided in each cell along the line of the railway system. The number of runs of loss cable will vary from one cell to another. If only one run of cable is provided for a cell, the optical fibres and couplers will not be necessary since the RF output of the BTS can be applied to the cable run directly.

It should be pointed out that other layouts may be used to distribute the signals between the BTS and cable runs. In particular, some optical fibres might carry several frequencies, in a known manner, or feed several coupling and amplifier devices in series in the downlink direction.

In the example illustrated in figure 1, the cable run 12 is located in the zone of the cell serviced by BTS 5 which is the closest to the cell serviced by BTS 6, and the run of loss cable 13 is located in the zone of the cell serviced by BTS 6 which is the closest to the cell serviced by BTS 5.

Steps are taken so that the beacon signal from BTS 6 is also transmitted via the cable run 12 and the beacon signal from BTS 5 is also transmitted via the cable run 13, these beacon signals then being transmitted with an attenuation relative to the other signals. Accordingly, a mobile station 44 serviced by BTS 5 and located within range of the cable run 12, when directed towards the adjacent cell, is able to pick up the beacon signal of the latter in order to prepare for the handover.

In order to obtain this partial overlap between cells, an optical fibre 36 in the bundle 26, carrying the beacon signal of BTS 6, is linked to the coupling and amplifier device 32 located in the station 2. Symmetrically, an optical fibre 35 of the bundle 25, carrying the beacon signal of BTS 5, is linked to the device 33 located in the station 3.

The device 32 is schematically illustrated in figure 3. Its structure is largely identical to that of the device 31 illustrated in figure 2, the same reference numbers being used to denote corresponding components. In the downlink direction, an additional basic coupler 46 translates in radio form the light modulation of the signal transmitted on the optical fibre 36 from the coupler-multiplexer 26 of the adjacent cell. At the output of this basic coupler 46, a RF amplifier 47 amplifies the frequency of the control channel, which is combined with the downlink signal S_D relating to BTS 5 to form the signal S_D^+ transmitted by the run of loss cable 12.

The amplifier 47 is controlled to have a lower gain than the amplifiers 42 of other frequencies so that the beacon signal from the adjacent cell is transmitted at a lower power than the radio signals transmitted from BTS 5. This ensures that the mobile stations will select the right BTS in the boundary zones.

In the example described above, where the cellular system is the of the FDMA type, transmission of the single frequency carrying the beacon signal of the adjacent cell into the end zone of the given cell is sufficient to provide the overlap of cells used to facilitate handover. In other types of cellular mobile communication system, it may be necessary to transmit a larger portion if not all of the signal formed by the base station of the adjacent cell into this zone.

In the embodiment of the coupling and amplifier device 32 illustrated in figure 4, the optical fibres 38 connected to the coupler-multiplexer 15 of the serviced cell are capable of carrying, in one direction or the other, all the frequencies used by the BTS 5, the couplers 40, 41 and the amplifiers 42, 43, having a sufficient bandwidth. Similarly, the downlink fibre 36 is capable of carrying all the frequencies used by the BTS 6 of the adjacent cell so that the device 32 is set up to transmit all the radio signals transmitted from BTS 6, within the coverage of the cable run 12, with an attenuation regulated by the

gain of the amplifier 47. Furthermore, the uplink signal S_U , picked up by the cable run 12 and the feeder cable 22, is forwarded to an additional RF amplifier 49, the output of which is linked to an additional RF/FO coupler 48. At the output of the coupler 48, the amplified uplink signal is carried as far as the
5 coupler-multiplexer 16 of the adjacent cell by means of another optical fibre 36.

The embodiment illustrated in figure 4 enables the mobile station to address the BTS of the adjacent cell before the handover is completed, which is useful for transmitting signalling in certain systems. This may also be used in cellular systems with a macro-diversity mode, i.e. in which a mobile station may
10 communicate simultaneously with several BTS close to the boundaries of cells.

The embodiments described above may be modified in various ways without departing from the scope of the invention. For example, the use of a multiplexing system and distribution by optical fibre depends more on the architecture of a specific cellular network than on demands imposed by the
15 invention, which may be equally well applied in situations where the antenna of each BTS consists of a single run of loss cable. Generally speaking, the invention will find applications wherever the cellular network has adjacent cells which use loss cables as transmission elements.

If the loss cables are used to transmit other mobile services, the
20 corresponding RF signals are mixed at the level of the feeder cables 21-24, at the output of devices 31-34. This secures an advantage in terms of flexibility since the overlap of cells proposed is produced only for the service or services which require it.

CLAIMS

1. Mobile communication system, comprising runs of loss cable disposed in succession along a zone of radio coverage and feeder means for feeding the cable runs from base stations of at least one cellular mobile communication network, wherein the feeder means have means for applying first radio frequency signals from a first base station of the cellular mobile communication network to a first cable run, and means for applying second radio frequency signals from a second base station of the cellular mobile communication network to a second cable run which is adjacent to the first run, and wherein the feeder means further have means for applying at least part of the second radio frequency signals to the first cable run.
2. System as claimed in claim 1, wherein said part of the second radio frequency signals is applied to the first cable run with a given attenuation relative to the first radio frequency signals as applied to the first cable run.
3. System as claimed in claim 1, wherein the feeder means further have means for applying at least part of the first radio frequency signals to the second cable run with a given attenuation relative to the second radio frequency signals as applied to the second cable run.
4. System as claimed in claim 1, wherein all the second radio frequency signals are applied to the first cable run.
5. System as claimed claim 1, wherein the part of the second radio frequency signals applied to the first cable run is limited to a frequency carrying a beacon signal from the second base station.
6. System as claimed in claim 1, wherein the feeder means are set up to apply the radio frequency signals from at least one of the first and second base stations to several adjacent cable runs.
7. System as claimed in claim 1, further having collection means to collect radio signals picked up by the runs of loss cable, wherein the collection

means have means for applying third radio frequency signals from the first cable run to the first base station and means for applying at least part of the third radio frequency signals to the second base station.

8. System as claimed in any one of the preceding claim 1, wherein the runs of loss cable extend through tunnels and wherein the feeder means are
5 positioned outside the tunnels.

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ABSTRACT

MOBILE COMMUNICATION SYSTEM USING LOSS CABLES AS TRANSMISSION ELEMENTS

Runs of loss cable are disposed in succession along a zone of radio coverage and coupled with feeder means from base stations of a cellular mobile communication network. The feeder means apply first radio frequency signals from a first base station to a first cable run and second radio frequency signals from a second base station to a second cable run, adjacent to the first run. They also apply at least part of the second radio frequency signals to the first cable run, preferably attenuated relative to the first radio frequency signals as applied to the first cable run, creating a zone of partial coverage between adjacent cells in order to facilitate operation of an automatic cell changeover during calls.

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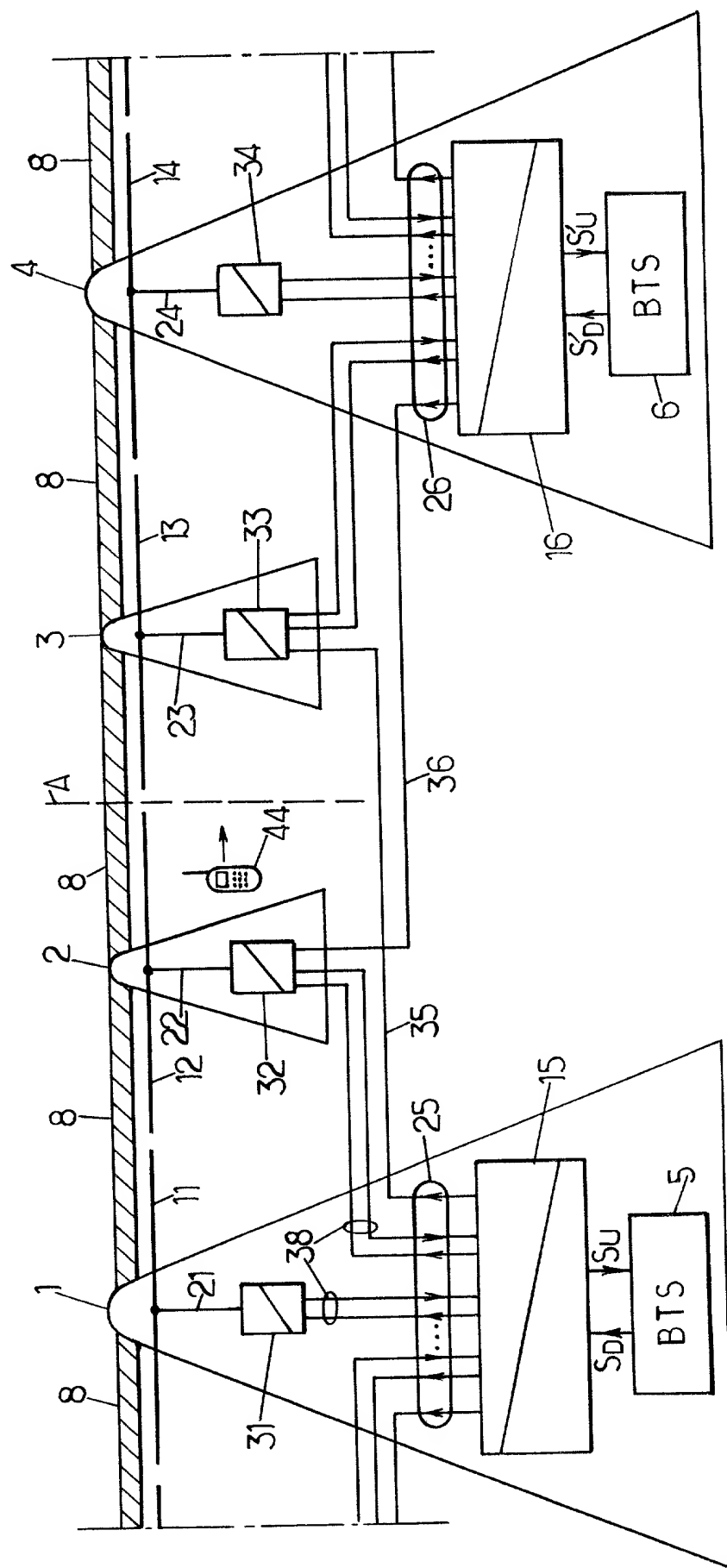


FIG.1.

FIG.2.

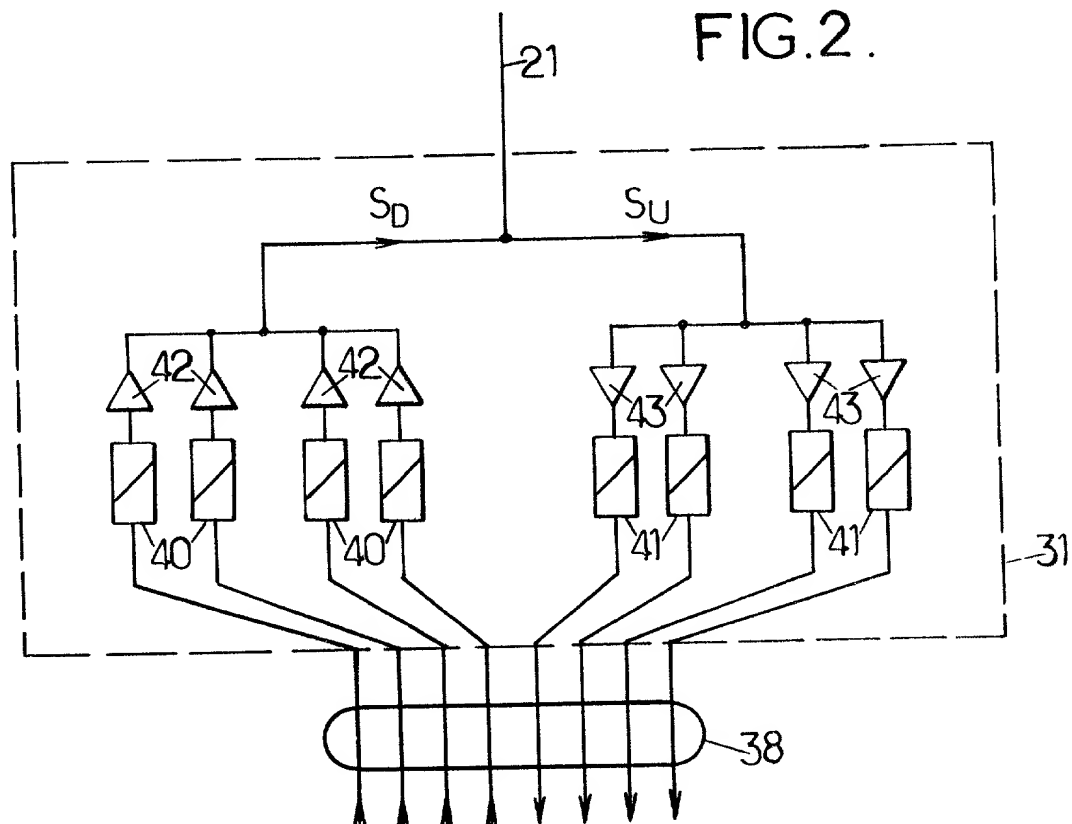


FIG.3.

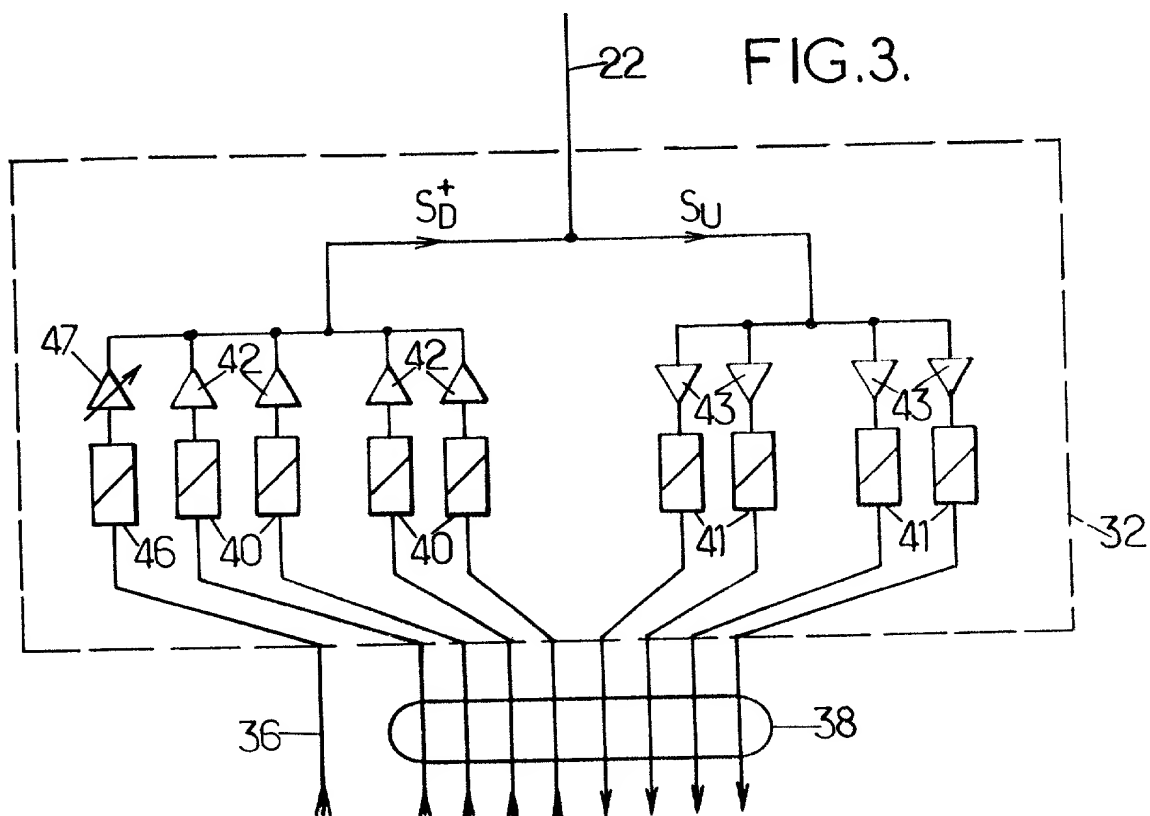
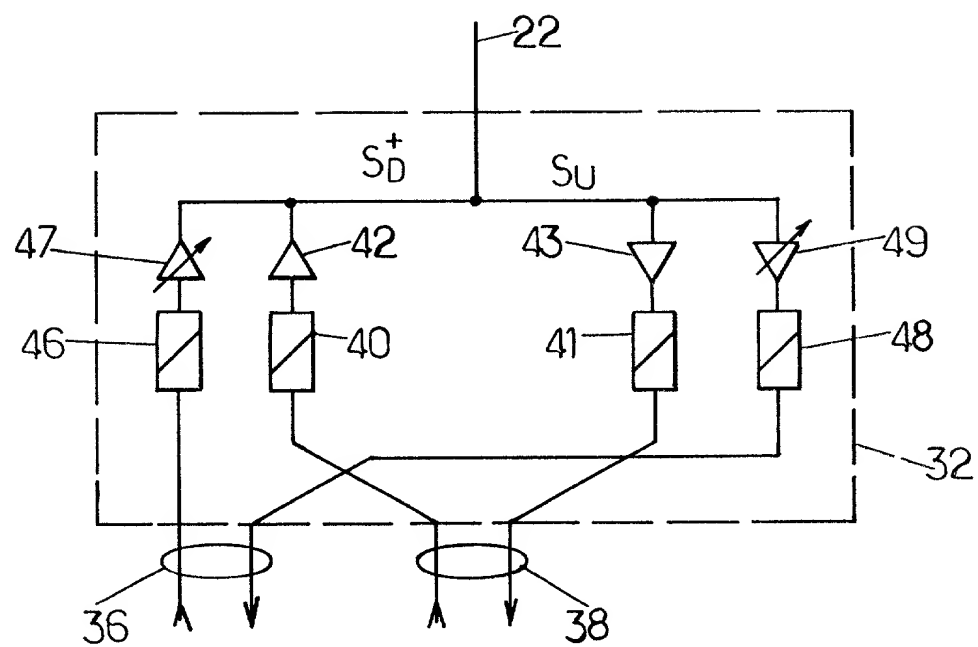


FIG.4 .



DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

**MOBILE COMMUNICATION SYSTEM USING LOSS CABLES AS
TRANSMISSION ELEMENTS**

the specification of which

X	is attached hereto.
	was filed on _____ as
	United States Application Number _____
	or PCT International Application Number _____
	and was amended on _____
	(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate Issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):			Priority Claimed	
FR 99 14904	France	26-11-99	X	
Number	(Country)	(Day/Month/Year Filed)	Yes	No
Number	(Country)	(Day/Month/Year Filed)	Yes	No

I hereby claim the benefit under title 35, United States Code, Section 119(e) of the United States provisional application(s) listed below:

_____ (Application Number)	_____ (Filing Date)
_____ (Application Number)	_____ (Filing Date)

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

_____ (Application Number)	_____ Filing Date	_____ (Status-patented, pending, abandoned)
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I hereby appoint Timothy N. Trop, Reg. No. 28,994; Fred G. Pruner, Jr., Reg. No. 40,779, Dan C. Hu, Reg. No. 40,025 and Ruben S. Bains, Reg. No. 46,532; my patent attorneys, of TROP, PRUNER & HU, P.C., with offices located at 8554 Katy Freeway, Ste. 100, Houston, TX 77024, telephone (713) 468-8880, my patent attorneys; with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence to Dan C. Hu, TROP, PRUNER & HU, P.C., 8554 Katy Freeway, Ste. 100, Houston, TX 77024 and direct telephone calls to Dan C. Hu, (713) 468-8880.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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